COATINGS. ENAMELS

UDC 666.293.52/.521.002.68

DEVELOPMENT OF UNDERCOAT ENAMELS BASED ON ALUMINUM-CONTAINING WASTE

E. A. Yatsenko,[1] A. P. Zubekhin,[1] and E. B. Klimenko[1]

Translated from Steklo i Keramika, No. 2, pp. 33 – 34, February, 2002.

The possibility of using aluminum-containing waste from metallurgical works to replace technical alumina in enamels is determined, and the limits for decreasing the content of adhesion oxides in the composition of undercoat enamels at the expense of the said waste are identified.

Under market economy conditions it is essential to develop resource-saving technologies, in particular, using waste generated by metallurgical works. The use of industrial waste makes it possible to solve a number of problems, such as using a less expensive material, improving the quality of the product, and improving the environment. In this context the purpose of the present study was to develop formulas for undercoat enamels to be used on 08kp steel, which would include high-aluminate waste from the Belaya Kalitva metallurgical works (Rostov Region).

The initial compositions selected were standard undercoat enamels (ÉSG-21, ÉSG-26, and ÉSG-31) used in the domestic industry. As a rule, Al_2O_3 is introduced into these compositions via technical alumina, and in our experiment we introduced Al_2O_3 via an aluminum-containing waste having the following chemical composition (wt.%): 15.14 SiO_2, 72.23 Al_2O_3, 1.95 F_2O_3, 1.77 CaO, 5.55 MgO, 0.32 TiO_2, 0.052 MnO_2, 2.22 K_2O, 1.59 Na_2O, and 3.46 Cl^-.

[1] South-Russian State Technical University, Novocherkassk, Russia.

The batches were prepared from the traditional materials used in the glass industry (sand, soda, etc.) with the only exception represented by the aluminum-containing water. The batch composition of the enamels is listed in Table 1.

The frits were melted in Alundum crucibles in an electrical furnace with Silit heaters at a maximum temperature of 1200°C with an exposure of 30 – 40 min. The glass melt was cooled in water, then a slip was prepared using the traditional method. The undercoat enamels were fired in a muffle furnace at 850°C, which is 50°C lower than the firing temperature of the standard undercoat enamels.

All the synthesized coatings had smooth, even, and uniformly colored surface.

As can be seen from Table 2, the waste-based enamels have fewer pinholes. It is known that iron in glass may be present in the following forms: trivalent in the form of FeO_4^{5-} and FeO_3^{3-} groups (lattice-forming), bivalent in the form of ions (modifiers of the lattice), and in the form of colloid-disperse oxides Fe_3O_4 and Fe_2O_3. In undercoat ena-

TABLE 1

Enamel	Weight content, %										
	sand	waste	technical alumina	boric anhydride	soda	Co_2O_3	NiO	MnO_2	calcium fluoride	MgO	Fe_2O_3
Standard:											
ÉSG-21	37.7	–	4.9	21.4	40.4	0.6	1.3	–	9.0	–	5.1
ÉSG-26	43.6	–	6.0	19.0	33.7	0.8	1.2	0.7	7.2	1.5	–
ÉSG-31	50.0	–	5.4	17.0	30.5	0.6	1.5	–	6.0	–	0.1
Based on waste:											
ÉSG-21	36.7	6.7	–	21.4	40.4	0.6	1.3	–	9.0	–	4.9
ÉSG-26	42.3	8.3	–	19.0	33.7	0.8	1.2	0.7	7.2	2.4	–
ÉSG-31	48.9	7.5	–	17.0	30.5	0.6	1.5	–	6.0	–	0.1

0361-7610/02/0102-0072$27.00

TABLE 2

Enamel	Firing temperature, °C	Outward appearance, grade*	Adhesive strength index, %	Presence of defects (pinholes), quantity per 1 dm^2
Standard:				
ÉSG-21	900	3	75	6
ÉSG-26	900	3	80	3
ÉSG-31	900	2	78	8
Based on waste:				
ÉSG-21	850	2	94	3
ÉSG-26	850	3	90	0
ÉSG-31	850	3	80	4

* The outward appearance of the coatings was graded as follows: 3) smooth, lustrous, uniformly tinted surface; 2) the same but less lustrous; 1) smooth dull surface, but nonuniformly tinted.

TABLE 3

Sample	Weight content of adhesion oxides, %		Adhesive strength index, %
	Co_2O_3	NiO	
1	0.8	1.2	90.0
2	0.6	0.9	89.5
3	0.4	0.6	88.5
4	0.2	0.3	51.0
5	0	0	0

mels based on the waste, the predominance of iron with a higher coordination number playing the role of a lattice modifier that loosens the structure and lowers the viscosity of the coating is more probable, which leads to fuller degassing of the enamel melt in firing and, consequently, to a decrease in the number of defects such as pinholes.

Apart from replacing technical alumina with the aluminum-bearing waste, we investigated the possibility of eliminating costly cobalt and nickels oxides from the undercoat enamel composition at the expense of ferric and manganese oxides contained in the same waste.

The experiments were performed on enamel ÉSG-26. The content of cobalt oxide and nickel oxide in the composition of this enamel was consecutively decreased (with an interval of 0.2% for cobalt and 0.3% for nickel). The adhesive strength of the fired samples was determined. It was measured using a device developed at the South-Russian Sate Technical University. The samples were subjected to a stepwise 7-mm stretching, after which the strength of adhesion was determined (Table 3).

It can be seen that as the Co_2O_3 content decreases to 0.4% and the NiO content to 0.6%, i.e., by half, the adhesion strength index decreases to 88.5%, which is 8% higher than the same parameter in the standard ÉSG-26 enamel (80%).

Based on the experimental data listed in Table 3, the dependences of the adhesion strength index on the content of Co_2O_3 and NiO were obtained using the least squares method:

$$Y = 5.64X_1^3 - 381.8X_1^2 + 398.76X_1 - 13.53;$$

$$X_2 = 1.5X_1\,,$$

where Y is the adhesion strength index, %; and X_1 and X_2 are the contents of Co_2O_3 and NiO, respectively.

In connection with the increased adhesive strength and the decreased firing temperature of enamel, the coating developed was also tested on other steel grades, in particular St.3 steel. The enamel spreads and adheres well not only on flat surfaces but also on surfaces with a curved profile.

The synthesized enamels can be recommended for coating on steel of 08kp and St.3 grades.